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Optimum organization of agricultural production in Chincha Valley, Peru

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OPTIMUM ORGANIZATION OF AGRICULTURAL PRODUCTION IN CHINCHA VALLEY, PERU

by

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I. INTRODUCTION

The purpose of this research is to apply a modern economic tool to the optimum organization of the farms in one area of Peru. The focus is on small farms in the Chincha Valley.

This study is involved with small farms, since the main objective of the government of Peru and the Alliance for Progress is to help the majority of the people engaged in the agriculture sector.

Aiding the small farmer to increase the productivity of his resources is only a starting point and a short run step toward greater productivity in the country. Accurate planning is a necessity for raising the farmer's standard of living.

We know that in the long run to achieve economic development, it is necessary to create job opportunities in other sectors, by educating the people and creating new skills in them, and starting a progressive industrialization.

Economic development is a consequence of new and better production possibilities that have been realized by particular communities from advances in technology, accumulation of capital, inprovement in skills, growth in population and improvements in economic organization (8).

Using a typical small farm, with a wide range of feasible production activities, and assuming limited amounts of operating capital, land, water, and labor, the optimum organization of the farm has been planned.

Another important feature of this research is that, for the first time in programming applications to farm planning, the capital limitations are considered monthly. In the United States this factor is not usually given

detailed treatment, since capital is not a scarce factor of production.

In developing countries such as Perú, capital is scarce and opportunity cost is high. For this reason we have attempted to design a linear programming model, which introduces monthly capital restrictions. In this manner the influence of this important factor of production on the optimum choice of activities can be more fully analyzed.

II. OBJECTIVES

The objectives of this study are as follows:

1. To define the optimum combination of crops which maximizes incomes of small farms, considering the limitations of capital, land, labor, and water in the Chincha Valley.

2. To analyze capital restrictions at selected levels, since capital is one of the most critical limitations in Peru.

3. To define the amount of land best suited for the resources of water, capital, and labor available on the farm.

4. To analyze the relationships of the restrictions of capital, water, land and labor to production activities suited to this area.

5. A more general objective of the study is to examine techniques and principles which may make a contribution to farming efficiency when applied in Peru.

III. STATEMENT OF THE PROBLEM

In the Chincha Valley uncertainty exists about the optimum combinations of crops produced on any one farm. This is reflected by the eleven different crops produced by the farmers of the area. Choice of the wrong cropping activities creates inefficiencies in the use of resources, especially capital and water.

Farmers seeking capital may choose between private lenders and the Banco de Fomento Agropecuario del Perú. Commercial banks and private lenders receive rates of interest ranging from 14 to 20 percent per annum. The Banco de Fomento Agropecuario del Perú charges a rate of 9 percent per annum. The advantage of borrowing from private sources is that the loan can be obtained quickly and requires less formal application procedure than the government sources of credit.

The international sources of credit, the World Bank, and the International Development Association have concentrated in public investments, such as roads, railroads, and electric power. With the exception of San Lorenzo Colonization, the rest of the farmers of the country do not receive loans from The World Bank, which offers credit at a rate of 5-1/2 percent interest (22, pp. 1-33).

Capital is scarce and expensive; therefore, it is especially important to study the best use of capital, analyzing capital requirements on a monthly basis to find the critical periods. Since rainfall in the Chincha Valley is negligible, water is another important restriction that the farmer must consider when planning the optimum combination of crops.

The goal of the government is to increase the level of income from the

small family farm, where the size of the farm is not in balance with the labor available from the operator and his family.

In one section of this study, the land resources typical of farmers of this valley have formed the basis for an analysis of the optimum combination of crops. In later sections, changes in the optimum crop program which would occur with increased land per farm were analyzed.

Since capital is one of the main restrictions, it also is analyzed at two different levels. This procedure could lead to better understanding of the requirements of capital and facilitate acquiring sufficient credit for the farmer.

Since the country is in a process of agrarian reform and is developing new areas of colonization in the coast and jungle, this study has tried to design a model that could provide information on the relationship of land and capital per farm to the optimum choice of crops and the level of income.

The size of the farm was increased in several test levels in the model, until its size reached the effective limit of other resources available on the farm.

IV. ANALYTICAL SETTING

A. Area Studied

1. Location

The Chincha Valley is located in the Ica Department, on the central coast of Perú, at latitude 13 26' 25" and longitude 76 08' 09". It is located 205 kilometers south from Lima and is connected by a surfaced highway.

2. Weather

The temperature during the summer (January, February, and March) has a maximum of 28°C and a minimum of 17°C. During the winter the temperature ranges to a maximum of 20°C and a minimum of 12°C. The humidity during the summer fluctuates from a maximum of 91 percent to a minimum of 50 percent. In the winter the range is from a maximum of 95 percent to a minimum of 55 percent. The precipitation during the summer is 0.2 mm and during the winter 2.0 mm (7).

3. Crops and agricultural problems

The crops cultivated in the Chincha Valley are the following: squash, peas, sweet potatoes, tomatoes, hybrid corn, beans, alfalfa, cotton, lima beans, corn and yuca.

The most common insects that attack the crops in the valley are: Anthomus Vestibus Bloom in the cotton and Heliothis Virescens in the corn. Elasmopalus lignoselles zell and Epitonia aporema are pests which frequently appear in beans.

B. Method of Analysis

The technique of linear programming is used in this study to estimate

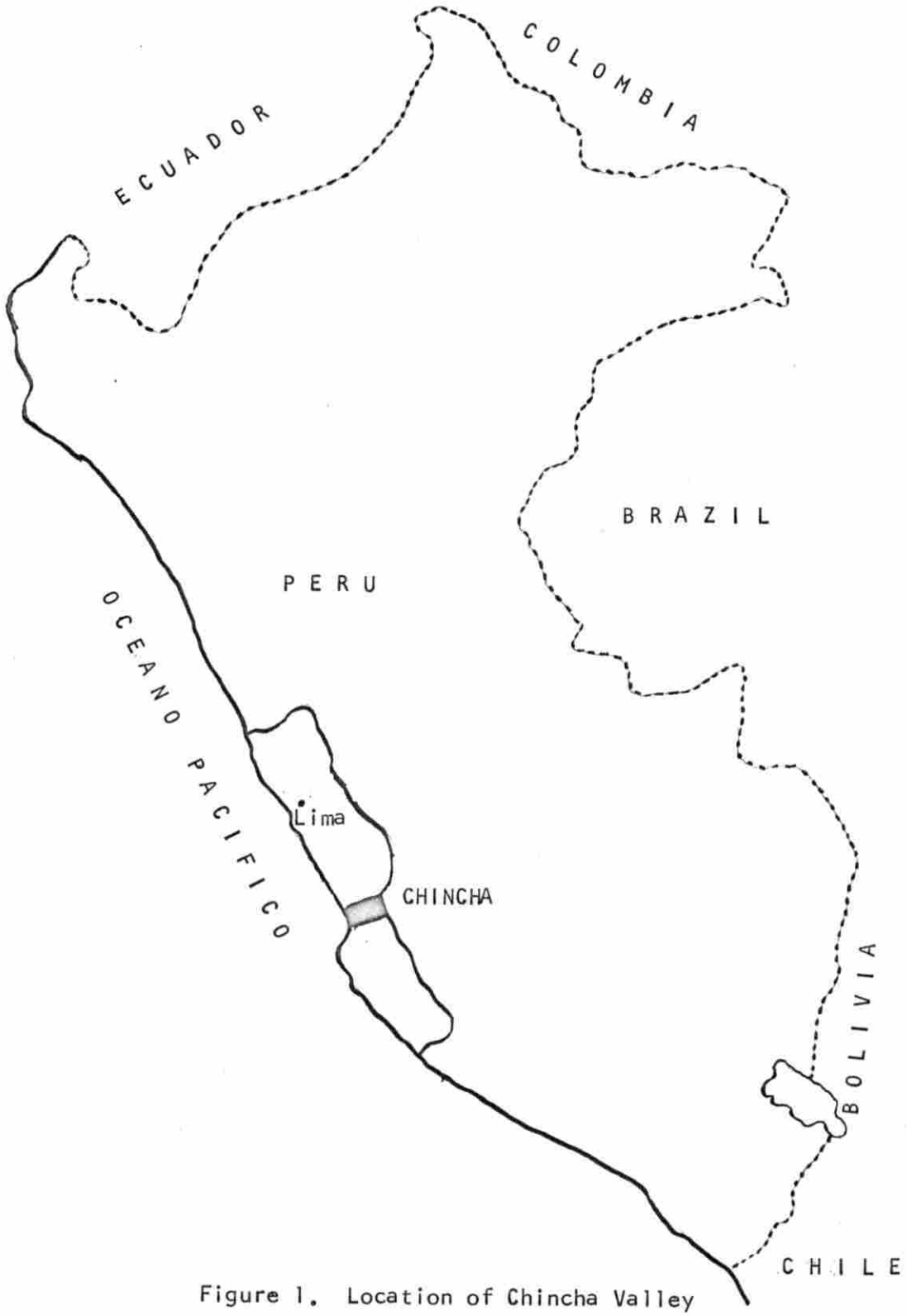

Figure 1. Location of Chincha Valley

maximum profits under different farm situations. Linear programming is a mathematical procedure which allows refinement and extension of the familiar budgeting procedure. Both methods consider allocation of a fixed supply of resources (land, labor, water, and capital) to alternative uses. Using budgeting techniques, only a limited number of possible enterprise combinations or plans can be considered because of the computational burden involved in laying each alternative plan (1).

The linear programming procedure allows simultaneous considerations of all feasible plans, where a feasible plan is one which is possible within the limitations of the resource supplies.

The plan which yields maximum income is automatically chosen from this array of feasible plans. It represents the optimum combination of enterprises for a producer operating within the designated resource restrictions who desires to maximize net income. These profit maximizing plans are therefore referred to as optimum plans.

1. Assumptions of linear programming

The most important assumptions of linear programming are the following: linearity, certainty, additivity, and finiteness.

a. Linearity Every activity considered in the model must be in the step of constant returns to scale. Each additional unit of output requires exactly the same amount of resources. For the farm as a whole, average and marginal returns vary as different combinations of enterprises are considered. Increasing supplies of one resource while holding other restrictions constant yields decreasing returns.

b. Certainty Prices and input-output coefficients indicate the transformation rate of resources to output and hence to revenue.

Coefficients and prices used in linear programming are singled valued. This may lead to errors in that the price uncertainty attaching to one product may be greater than another. One enterprise is treated like all others even though its price uncertainty may be greater.

In order to define these values it is advisable to use the mean of the values in the area. It is also necessary to be familiar with the price elasticity of demand for the output of every activity in order to interpret the solutions in case of exaggerated results.

c. Additivity In additivity the results of two or more units of different activities carried on simultaneously are additive. This means the combined input is the sum of the inputs of the separate activities, and the combined output is the sum of the outputs of the separate activities (9).

d. Finiteness Linear programming assumes a limited number of relevant alternative activities. Since linear programming makes this assumption, we are forced to choose a certain number of the most relevant activities to be included in the model.

The most relevant activities are frequently defined on the basis of the experience of the farmer. If the planner had an unlimited number of alternatives, he would never succeed in programming them, because he would never finish describing additional activities (14).

2. Model

This model is designed to specify the plan which will give maximum income, considering the limitations of capital, water, land, and labor in the Chincha Valley of Perú.

The modified simplex method has been used to find this optimum solution. The modified simplex solution rests on two simple conditions. First, the optimum program for each situation is one that gives the highest ratio of income to limiting resources, i.e., the income resource ratio for each limitational resource is higher than would be provided by any other program. Second, a modified simplex solution can be derived whereby each new activity introduced gives a return to capital, i.e., increase in income per unit of capital used or some other limiting resource, higher than any other activity that could have been introduced. When the optimal program is finally reached the ratio of total income to total capital used is higher than for any other program.

Knowing the actual technology developed in the Chincha Valley, and the capacity of work of the members of a family farm, it was also possible to find the optimum area for this family to operate. It is necessary to emphasize that the business size of operation in Chincha Valley could be increased with the combined improvement of technology, education, increase of water supply, and area of land for the small farmer.

a. Objective function The objective of the model is maximizing net farm income for the resources controlled, i.e., maximization of the value of the program.

The profit equation has been determined considering the net price for individual activities, i.e., gross receipts minus variable costs of production. This is called the C row in the thesis and shows the net price for each activity per unit of output.

In developing the net price for an activity it is implicitly assumed

that all the products are sold during the planning period.

Subtracting all fixed production expenses from the value of the program could provide an estimate of net farm income (4).

b. The profit equation is the following:

$$\pi = ax_1 + bx_2 + bx_3 \ldots\ldots + nx_{11}$$

The value of the program in the final iteration is the sum of the products when the net price of each activity is multiplied by the number of units of those activities that are in the solution.

c. Resource restrictions The main feature of this model was the definition of capital restrictions by months in order to determine which were the most critical months. The capital requirement coefficients were estimated for each month of the year.

Turning to some well known examples such as Swanson, Heady (1958) and Candler (1956), where capital had been included as an effective constraint, we observe that it is always in the form of a single linear relationship.

$$Po \geq \sum_{j=1}^{n} vj \quad Pj$$

where Po is the capital limitation and where it is assumed that there are n possible acitivities, and that the capital requirements of any particular one can be expressed in the form rj Pj, where Pj states the level at which the activity in question is to be carried on, and where rj is a constant characteristic of the activity (19).

It is difficult to give a realistic meaning to the relationships given in this form. The expression presented in the above form works under

conditions where the coefficients refer only to a period of time between the beginning of a farm year and the point when sales begin.

This model breaks down the capital restrictions by months in the following way:

Time Period	Capital Available		Real Activities
1	P_1	$\geq$	$ax_1 + bx_2 + cx_3 + dx_4 \ldots\ldots + cx_{11}$
2	P_2	$\geq$	$dx_1 + fx_2 + mx_3 + lx_4 \ldots\ldots + hx_{11}$
3	P_3	$\geq$	$cx_1 + dy_2 + ny_3 + px_4 \ldots\ldots + bx_{11}$
4			
.			
.			
.			
.			
.			
12	P_{12}	$\geq$	$mx_1 + lx_2 + cx_3 + dx_4 \ldots\ldots + nx_{11}$

The restriction does not specify that all capital must be utilized but gives only the upper limit of capital available in each month.

On this basis the enterprises that do not exceed the limitation of the monthly capital available and that give the maximum return to the operator can be chosen in the programming process.

Most farmers have limited amounts of capital at their command. Hence, the capital restriction used for one programming situation does not apply to another farm with more or less capital available. In many farming regions, a large number of farms have similar soil, acreage, building, and family labor restrictions, whereas capital restrictions are highly variable (6).

The next important limitation included in the model was the water restriction by months.

Time Period	Water Available		Real Activities								
1	W_1	$\geq$	ax_1	+	bx_2	+	cx_3	+	+	ex_{11}	
2	W_2	$\geq$	dx_1	+	cx_2	+	fx_3	+	+	mx_{11}	
3	W_3	$\geq$	cx_1	+	dx_2	+	ex_3	+	+	nx_{11}	
.											
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.											
12	W_{12}	$\geq$	dx_1	+	nx_2	+	lx_3	+	+	gx_{11}	

where W_1, W_2, ... W_{12}, represent available water per month and x_1, x_2, ... x_{11}, represent activity levels and a, b, ... n, indicate the quantity forwater required per unit of activity.

The other restriction considered was land. In the first analysis, the size of the farm programmed was typical of many small farms in the Chincha Valley.

The next restriction was labor. It was considered in the system of equations as the monthly availability of hours of work. The coefficients were the requirements of work for every crop in each month.

Time Period	Labor Available		Real Activities								
1	L_1	$\geq$	ax_1	+	bx_2	+	cx_3	+	lx_{11}		
2	L_2	$\geq$	bx_1	+	cx_2	+	dx_3	+	fx_{11}		
3	L_3	$\geq$	cx_1	+	dx_2	+	ex_3	+	mx_{11}		

4
.
.
.
.
.
12 $L_{12} \geq dx_1 + mx_2 + nx_3 \ldots\ldots + zx_{11}$

This system of inequalities must be transformed into a system of equalities by adding a matrix of slack variables to the right hand side of the system.

The Z row or opportunity cost shows for each activity the value of other enterprises which must be sacrificed to produce one more unit of output.

d. Shadow prices The Z-C value or the shadow price indicates how adding an additional unit of any activity, including a disposal activity, will change the value of the program. The signs are reversed, however. A minus value in one real activity means that adding one hectarea of this activity the value of the program is going to be increased by this value (14).

One of the remarkable properties of the allocative programming solution is the emergence of marginal value productivity estimates for scarce capital, land, water and labor resources. The estimates indicate the worth or value of one added unit of a scarce resource as a productive imput. These imputed values assigned to resources that limit higher farm plan profit levels are called shadow prices.

3. Alternative enterprises

For this study of farms in the Chincha Valley eleven different crops were defined. These were crops that had been produced during many years

with acceptable yields.

These crops were: squash, peas, sweet potatoes, tomatoes, hybrid corn, beans intercropped with corn, alfalfa, cotton, lima beans, corn and yuca.

The level of technology considered is the actually achieved level on farms of this type. The data particularly labor requirements, capital requirements, water need, and expected yields were discussed with the successful farmers and technicians working in the area. The characteristics of the crops included follow.

a. Squash The period of production is nine months, typically starting in September with the preparation of the land. The planting is in October. Disease control measures are carried out in October through February. The crop is irrigated from November through April and harvested in May.

b. Peas The length of the production period is five months. Preparation of the land takes place in May and planting in June. Disease control starts in June and continues through September. Fertilizer is applied in July and irrigations from June until September. September is the harvest season.

c. Sweet potatoes The production period extends for six months, with the preparation of the land taking place in April and planting in May. Disease control measures start in May and are completed in July. Fertilizer is applied in June and irrigation extends from May until September. The harvesting season is in September.

d. Tomatoes The preparation of land begins in January with planting in February. Disease control starts in February and continues until

June. Fertilizer application is made in March. Irrigation starts in February and is completed by the end of June. The crop is harvested in June. Thus, the production period is of six months duration.

e. Hybrid corn The land is prepared in July and planting takes place in August. Disease control starts in August and continues into November. Fertilizer is applied in August and September. Irrigation starts in August and is finished in November and the crop is harvested in December. The total length of the production period is six months.

f. Alfalfa Alfalfa is a perennial crop that can be expected to maintain acceptable stands for four years. The preparation of the land takes place in April and planting in May. Disease control and fertilizing starts in June and continues for ten months. Irrigation starts in May each year.

g. Cotton The period of production is ten months. Preparation of the land starts in July and planting is in August. Disease control begins in September and terminates in March. The application of fertilizer is made in September and October. Irrigation starts in August and is finished in March. Harvesting is in April.

h. Lima beans The length of production is eleven months. Preparation of the land takes place in December. Planting of lima beans occurs in January with disease control starting in January and terminating in November. The harvest takes place in November.

i. Corn The period of production is five months. The preparation of land takes place in March; planting in April. Disease control is carried out from April until June. The application of fertilizer is made

in April and May. Irrigation starts in April and is ended in July. The harvest is in July.

j. Yuca The period of production is ten months with the preparation of the land beginning in August. The planting takes place in September. It is not necessary to employ disease control measures. Fertilizer is applied in October. Irrigation starts in September and is terminated in April. Harvesting takes place in May.

An estimate of net income per hectarea by activity found in the area is shown in Table 1.

Table 1. Annual net income by crop

Crop	Net Income (soles)
Squash	9,023.00
Peas	7,617.13
Sweet Potato	6,927.99
Tomato	11,535.51
Hybrid corn	6,030.39
Beans with corn	10,182.54
Alfalfa	9,644.11
Cotton	4,669.37
Lima beans	11,431.17
Corn	9,295.15
Yuca	13,018.25

4. Resource restrictions

In setting up a linear programming model it is necessary to define which resources may limit the activities. In this model. capital, land, labor and water were defined as the most relevant restrictions.

a. Capital In developing countries such as Peru capital is a critical resource. The commercial banks and private lenders are receiving a rate of interest of 14 to 20 percent per year. The Banco de Fomento Agropecuario del Peru charges a rate of interest of 9 percent when the amount of loan is less than 100,000.00 soles and 10 percent when the loan is larger than this amount (2). In order to handle the capital in a more detailed way it is advisable to define capital requirement coefficients on a monthly basis for each activity.

A basic problem in Perú is to improve the distribution and mobility of capital among alternatives within agriculture. Opportunity costs become important. The farmer must develop an acute sense of timing for seasonal problems in finance and for life cycle problems. It is necessary to recognize the importance of the time pattern as an ingredient of the budget. Therefore it means if capital is going to be included in linear programming as a limiting factor, it is necessary to take into account its seasonality. In other words, so-called capital profiles must be developed for planning capital use.

Harrison, in 1956, said that the capital profile, for individual enterprises, must be taken over a period of time. Clark and Simpson in presenting an example of planning with linear programming in 1959 suggested, "There seems no very good reason why capital should not be handled in the same way as labor". Cann in discussing working capital needs points out that it has two dimensions, quantity and time. If in fact there is a limit on the supply of seasonal capital, it is necessary to determine what combination of enterprises will maximize farm income, subject to all other

physical and preferential restrictions. If seasonal capital is a limiting resource, then it will play a role in defining the optimum plan. If it is not limiting then it need not be considered as a restriction in the programming model.

The capital restrictions were considered by months for two different levels. Other resources were held at fixed levels in the conventional manner. At each step in the solution, the activity yielding the highest return to capital was introduced into the plan to the maximum amount permitted by the most limiting resource. When this criterion is followed, it results in a situation of successive plans which maximize the return to capital, within the limitations improved by other resources. The optimum plan for any desired amount of capital may be obtained by linear interpolation between successive plans.

The capital requirements for every activity represents the capital needed for every month's operation. This included operating expenses, not fixed costs, such as land and buildings. Only the expenses paid by the tenant were included. Rent is not included since it usually can be paid at the end of the year with the receipts from the current crop. The cost of family labor was not included as a variable cost. This had the result of including only the variable expenses associated with the production of crops.

The value of the program which appears in the solution under these circumstances provides an estimate of the money available to meet fixed costs and to provide for living expenses of the farm family. The capital restriction for the small farm was defined taking into consideration the

actual capacity of credit per month of the farmer.

The Banco de Fomento Agropecuario del Perú limits capital per month to 72 percent of the value of the land divided by 12 months. Assuming the value of land is 50,000 soles per hectarea; then

$$\frac{50{,}000 \times 4 \text{ hectareas} \times .72}{12} = 12{,}000 \text{ soles (2, pp. 20).}$$

The requirements of capital by months for each activity is presented in Table 2.

b. Water This restriction will decide the optimum combination of crops from the point of view of efficient use of water. As was mentioned in describing the characteristics of the Chincha Valley, the precipitation is very small, therefore it is necessary to handle this restriction wisely.

The sources of water that farmers of this area have are three: water from wells, from lakes, and from the river. Water from wells is available all year but the supply available during any time period is limited. In the whole valley there are 167 wells in operation. Every pump has a capacity of 288 m^3 per hour (81 lts. per second). The pumps are operated 12 hours per day. They are used about 100 days per year. The farmer pays 60 soles per irrigation per hectarea when he uses the water from the wells.

Water from the lake is used during September, October, November, and December. The farmer has to pay 45 soles per irrigation per hectarea when he uses lake water.

Water from the San Juan river is used in January, February, and March. The farmer pays 12 soles per irrigation per hectarea when he uses river water. The annual volume of the river is 68'855,796 m^3. And the annual

Table 2. Capital requirements by month and activity; for small farms in the Chincha Valley *

	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11
	Squash	Peas	Sweet Potato	Tomato	Hybrid corn	Beans with corn	Alfalfa	Cotton	Lima beans	Corn	Yuca
January	3199.	0	0	790.	0	0	0	5826.	1391.	0	1890.
February	3611.	0	0	2141.	0	0	0	6235.	2539.	0	2011.
March	3855.	0	0	4057.	0	0	0	6676.	2762.	0	2223.
April	3976.	0	838.	5356.	0	0	1013.	7138.	2918.	825.	2345.
May	0	1163.	1284.	6707.	0	0	1834.	0	3144.	1212.	2785.
June	0	1773.	2151.	9044.	0	860.	2051.	0	3394.	2903.	0
July	0	3040.	2464.	0	803.	1639.	2269.	1043.	3573.	3642.	0
August	0	3786.	2585.	0	2229.	2778.	2486.	1395.	3814.	3904.	0
September	790.	4882.	3152.	0	3853.	3398.	2703.	2641.	3990.	0	676.
October	2041.	0	0	0	4574.	0	2921.	4537.	4182.	0	1257.
November	2487.	0	0	0	4904.	0	3138.	5133.	7568.	0	1518.
December	3005.	0	0	0	4982.	0	3355.	5583.	1115.	0	1769.

* The values are expressed in soles.

volume of reservoirs is 22'800,000 m^3.

Farmers are allowed to use a limited volume of water per farm in each month as decided by an irrigation cooperative in the Chincha Valley. The monthly restriction of water is shown in Table 3.

The requirements of irrigations per crop or activity are presented in Table 4.

c. Management Some managers may have the capacity to work effectively with a small enterprise but fail with a larger one. This depends mainly on the skill and level of education of the farmer. Management ability varies considerably among farm operators. However, coefficients employed in crop activities reflect the level of competency of the operator.

The level of management of the small farms in the Chincha Valley is relatively low because of the poor training and education among the operators. However, this factor has been taken into account in estimating production coefficients (4).

A superior manager is identified by his superior achievement level. He has higher crop yields, and uses his capital and labor more efficiently. An inferior manager exhibits opposite characteristics. Neither extremes of superior or inferior management abilities were assumed for Chincha Valley farm operators. Rather, an average or typical manager was assumed (16, p. 177).

The category of average management is reflected in average yields, labor requirements, and fertilizer response for crop activities.

d. Labor The labor included for all farm situations was that which could be supplied by the operator and his family. Hired labor is not

Table 3. Limit of water per farm by month

Month	Irrigations per farm	Volume[a] per farm
		(m^3)
January	7	2,016
February	8	2,304
March	8	2,304
April	10	2,880
May	9	2,592
June	10	2,880
July	10	2,880
August	12	3,456
September	12	3,456
October	12	3,456
November	7	2,016
December	6	1,728

[a] 288 m^3 per irrigation

Table 4. Irrigation requirements by month and activity for small farms in the Chincha Valley*

	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11
	Squash	Peas	Sweet potato	Tomato	Hybrid corn	Beans with corn	Alfalfa	Cotton	Lima beans	Corn	Yuca
January	2			5			2	4	2		2
February	4			1			2	4	2		2
March	4			2			2	5	1		2
April	2		5	1			5		2	5	5
May		5	1	1			2		2	4	2
June		2	2	3		5	2		1	6	2
July		5	2		5	2	2	5	2	4	2
August		6	2		4	2.5	2	3	2	4	2
September	5	4	1		6	3.5	2	3	1		2
October	2				6	4	2	7	2		2
November	4				2		2	5			2
December	4							4	5		2

* The values are expressed in irrigations.

considered.

An average of six members per family was assumed. A maximum of 480 hours of labor per month was considered available (2 workers x 8 hours x 30 days = 480 hours). This did not mean that the farmer was not going to rest during some weeks during the year. Requirements of labor for each crop were estimated by hours per month. These estimates are presented in Table 5.

e. Land The soil considered is typical for the aluvial and coluvial soil association. The level of productivity of the soil is the actual average obtained in the Chincha Valley.

The area of land, 4 hectareas, used in the analysis was that of the typical small farm. However, in order to test the effect of adding more land while other resources remained unchanged, the size of the farm was increased to 8 hectareas in situation IV and V.

Table 5. Labor requirements by month and activity for small farms in the Chincha Valley*

	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11
	Squash	Peas	Sweet potato	Tomato	Hybrid corn	Beans with corn	Alfalfa	Cotton	Lima beans	Corn	Yuca
January	42						10	52	26		2
February	52			126			52	28	54		2
March	76			58			10	25	25		34
April	2		5	37			5	82	29	100	2
May		5	101	77			18		58	86	124
June		50	6	243			12		57	38	
July		85	6		5	66	12	5	50	142	
August		38	2		108	50	52	35	66		
September		78	281		70	52	12	96	57		42
October	42				38	104	52	31	42		34
November	20				34		12	21	343		34
December	76				124		52	20			32

* The values are expressed in hours.

V. RESULTS AND DISCUSSIONS

In this section discussions are presented to evaluate the results of the linear programming computations of the empirical data. For all the situations the requirements of inputs for every activity were defined and presented in the description of the limitations and activities.

In this study the level of restrictions in capital and land area was changed in order to analyze the effect these shifts would have on shadow prices, on the optimum mix of activities, and on the value of the program. However, the restrictions of labor and water are assumed to be fixed.

The total net income per family farm is assumed to be the value of the program minus 10 percent the rate of interest for the capital used. Rent of land is not considered as a cost since it is assumed that the farmer owns the land. The small farmer does not pay taxes.

A. Situation I

Optimum farm plan assuming 4 hectareas of farm and 12,000 soles of monthly restrictions of capital

The factors of capital and land were analyzed with respect to the eleven crops cultivated in the Chincha Valley. This case considers the group of farmers whose maximum monthly availability of capital is restricted to 12,000 soles. The average size farm for this group was 4 hectareas. Under these conditions the result of the computations of the program was 4 hectareas of yuca with a value for the program of 52,073 soles (see Table 6).

An agricultural planner should ask himself if such a result is consistent, given the degree of uncertainty with respect to price, production and

Table 6. Optimum farm plan and associated data for the Chincha Valley of peru under restrictions of land and capital

Activity code	Activity description	Level of activity (hectareas)	Capital not used (soles)	Capital required (soles)	Cost of capital (soles)
P11	Yuca	4.00			
R01	Cap. Jan.		7,290.00	4,710.00	410.00
R02	Cap. Feb.		6,805.00	5,195.00	476.20
R03	Cap. March		6,320.00	5,680.00	473.33
R04	Cap. April		5,835.00	6,165.00	462.37
R05	Cap. May		4,073.73	7,926.27	528.41
R06	Cap. June		12,000.00	--------	------
R07	Cap. July		12,000.00	--------	------
R08	Cap. Aug.		12,000.00	--------	------
R09	Cap. Sept.		11,265.00	735.00	24.50
R10	Cap. Oct.		8,940.00	3,060.00	76.50
R11	Cap. Nov.		8,295.00	3,705.00	61.75
R12	Cap. Dec.		7,775.00	4,225.00	35.20
Total		4.00			2,548.26

Value of the program	52,073.00 soles
Cost of capital	2,548.26 soles
Net income for family farm	49,524.74 soles

the price elasticity of the products.

It has been established in Perú that the price elasticity of demand for yuca is very low with great fluctuations of price. If only yuca is produced in the whole valley of Chincha the price of this product is going to be reduced drastically.

There are two alternative methods for dealing with this situation: 1) develop a model and obtain a solution using the low price expected for yuca if the entire valley is planted to this crop; 2) limit the area used for yuca production to a level which will not greatly change the price of yuca in the market.

The first alternative will distort the net income and eliminate the crop completely from the final result. The second alternative seems more reasonable since the yuca activity has the characteristics of low requirements of capital and no disease problems. The exact determinations of the quantity of yuca that will not change significantly its price in the market requires a deeper study of the market of the product, which could be subject of another thesis. Furthermore, the government of Perú should make such studies with respect to all the products in order to have a more realistic basis for planning.

Limiting the area in the valley allocated to yuca to one-fourth of the available land greatly reduces the chances of a sharp negative price effect. Under this assumption the model provided the outcome shown in Table 7.

The value of the program was reduced from 52,073.00 soles to 46,377.00 soles. This plan is more realistic, because this combination of crops would not produce drastic changes in the prices of the products in the

Table 7. Optimum farm plan and associated data for the Chincha Valley of Peru under restrictions of land, capital and maximum one-fourth total area in yuca

Activity code	Activity description	Level of activity (hectareas)	Capital not used (soles)	Capital required (soles)	Cost of capital (soles)
P14	Tomato	0.6980			
P09	Lima Beans	1.4631			
P06	Beans with corn	0.8390			
P11	Yuca	1.0000			
R01	Cap. Jan.		8,235.60	3,764.40	376.44
R02	Cap. Feb.		5,491.16	6,508.84	596.64
R03	Cap. March		3,706.18	8,293.82	691.15
R04	Cap. April		2,450.77	9,549.23	716.17
R05	Cap. May		735.65	11,264.35	750.95
R06	Cap. June		--------	12,000.00	700.00
R07	Cap. July		5,396.21	6,603.79	330.19
R08	Cap. Aug.		4,087.59	7,912.41	329.68
R09	Cap. Sept.		3,126.47	8,873.53	295.78
R10	Cap. Oct.		5,116.39	6,883.61	172.09
R11	Cap. Nov.		--------	12,000.00	200.00
R12	Cap. Dec.		9,312.42	2,687.58	22.39
Total		4.0000			5,181.48

Value of the program	46,337.04 soles
Cost of capital	5,181.48 soles
Net income per family farm	41,155.56 soles

markets. Deducting the cost of capital, the net income per farm family had been reduced from 49,524.74 soles to 41,155.56 soles.

Upon examination of Table 7 the contribution of the model at this stage was a clear picture of the most critical months with respect to the requirements of capital.

Shadow prices: (see Table 8). If we replace one hectarea of real activity now in the optimal solution with each of the following real activities, which were not in the optimal solution, holding the area of the farm at 4 hectareas, the value of the program would be reduced in each case by the following amount:

Activity increased by one hectarea		Reduction in the value of the program, soles
P01	Squash	1,290.04
P02	Peas	2,716.45
P03	Sweet potato	3,468.04
P05	Hybrid corn	4,547.64
P07	Alfalfa	1,079.50
P08	Cotton	5,933.24
P10	Corn	1,225.24

The last unit of each of the resources which were restrictive to this program, contribute the following amount to the value of the program.

Contribution of last unit of resource to the value of the program:

R06	Capital in June, one sol	0.16 soles
R11	Capital in November, one sol	0.10 soles
R13	Land, one hectarea	10,040.37 soles

This means that if we increase by one-hundred soles the capital in June or November, the value of the program would be increased by approximately 16 soles and 10 soles respectively. If we increase by one hectarea the

Table 8. Shadow prices and cost rows of the real and disposal activities*

1	B	P01	P02	P03	P04	P05	P06
	46,337.03	1,290.03	2,716.44	3,468.04	0.00	4,547.64	0.00
C. row	0.00	9,023.00	7,617.13	6,927.99	11,535.51	6,030.39	10,182.54
2	P07	P08	P09	P10	P11	R01	R02
	1,079.49	5,933.24	0.00	1,225.24	0.00	0.00	0.00
C. row	9,644.11	4,669.87	11,431.17	9,295.15	13,018.25	0.00	0.00
3	R03	R04	R05	R06	R07	R08	R09
	0.00	0.00	0.00	0.16	0.00	0.00	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	R10	R11	R12	R13	R14		
	0.00	0.10	0.00	10,040.37	2,876.33		
C. row	0.00	0.00	0.00	0.00	0.00		

* The values are expressed in soles.

limitation of land, this would increase the value of the program by 10,040.17 soles. Relaxing the restriction on yuca production would also increase the value of the program by 2,876.34 soles.

B. Situation II

Optimal farm plan assuming 4 hectareas of land; 12,000.00 soles monthly limitation of capital; and monthly restriction of water as indicated in Table 3

Another limitation that was studied in the model was the water restriction, since along the coast of Perú it is one of the main restraints in the agricultural sector.

Detailed information has been presented in the water restriction section, where the monthly requirements of water for every crop and the quantity of water available to be usèd by the farmer were presented.

After including these twelve equations in the system, the computation gave the results shown in Table 9. The value of this program was reduced from 46,337.04 soles to 45,620.46 soles. Deducting the cost of capital, the net income per farm family had been reduced from 41,155.56 soles to 40,900.88 soles.

If we compare this result with that in the first model, we find that the level of lima beans has been reduced from 1.4631 hectareas to 1.0185 hectareas.

The plan resulting from model II also includes a new activity, alfalfa. The area of beans intercropped with corn and the level of the tomato activity (P04) have increased because they make better use of the water resources.

Table 9. Optimum farm plan and associated data for the Chincha Valley of Peru under restrictions of land, capital, water, and maximum of one hectarea total area in yuca

Activity code	Activity description	Level of activity (hectareas)	Capital not used (soles)	Capital required (soles)	Cost of capital (soles)
P04	Tomato	0.7407			
P11	Yuca	1.0000			
P06	Beans with corn	0.8334			
P09	Lima beans	1.0185			
P07	Alfalfa	0.4074			
R01	Cap. Jan.		8,820.30	3,179.70	317.97
R02	Cap. Feb.		6,528.48	5,471.52	501.55
R03	Cap. March		4,760.85	7,239.15	603.26
R04	Cap. April		3,106.25	8,893.75	667.03
R05	Cap. May		1,099.40	10,900.60	726.70
R06	Cap. June		290.95	11,709.05	683.02
R07	Cap. July		6,069.56	5,930.44	296.52
R08	Cap. Aug.		4,786.12	7,213.88	300.57
R09	Cap. Sept.		3,818.16	8,181.84	272.72
R10	Cap. Oct.		5,785.42	6,214.58	155.36
R11	Cap. Nov.		2,086.10	9,913.90	165.23
R12	Cap. Dec.		8,440.89	3,559.11	29.65
Total		4.0000			4,719.58

Value of the program	45,620.46 soles
Cost of capital	4,719.58 soles
Net income per family farm	40,900.88 soles

Table 9. (Continued)

Activity code	Activity description	Level of activity (hectareas)	Capital (soles)	Water not used (irrigations)	Water required (irrigations)
R15	Water, Jan.				7.00
R16	Water, Feb.			3.96	4.04
R17	Water, March			2.81	5.19
R18	Water, April				10.00
R19	Water, May			2.52	6.48
R20	Water, June				10.00
R21	Water, July			2.22	7.78
R22	Water, Aug.			5.03	6.97
R23	Water, Sept.			9.11	2.89
R24	Water, Oct.			7.48	4.52
R25	Water, Nov.			3.29	3.71
R26	Water, Dec.			4.37	1.63

Shadow prices: (see Table 10). If we replace one hectarea of a real activity now in the optimal solution by each of the following real activities which were not in the optimal solution, holding the area of the farm at 4 hectareas, the value of the program would be reduced in each case by the following amount:

Activity, increased by one hectarea		Reduction in the value of the program, soles
P01	Squash	10.69
P02	Peas	1,571.18
P03	Sweet potato	2,534.47
P05	Hybrid corn	2,173.57
P08	Cotton	4,856.00
P10	Corn	887.39

The last unit of each of the resources which were restrictive to the program, contributed the following amount to the value of the program.

Contribution of last unit of resources to the value of the program:

R13	Land, one hectarea	8,203.95 soles
R15	One irrigation, January	360.04 soles
R18	One irrigation, April	54.83 soles
R20	One irrigation, June	492.17 soles

Relaxing the restriction on yuca production would also increase the value of the program by 4,814.29 soles.

C. Situation III

Optimum farm plan assuming 4 hectareas of land;
12,000.00 soles monthly limitation of capital;
480 hours of labor per month; and monthly limitation
of water as indicated in Table 3

In situation III a further modification of the resource restrictions was made. This modification was the addition of a monthly labor restriction.

Table 10. Shadow prices and cost rows of real and disposal activities*

1	B	P01	P02	P03	P04	P05	P06
	45,620.45	10.69	1,571.17	2,534.47	0.00	2,173.56	0.00
C. row	0.00	9,023.00	7,617.13	6,927.99	11,535.51	6,030.39	10,182.54
2	P07	P08	P09	P10	P11	P12	P13
	0.00	4,856.00	0.00	887.38	0.00	0.00	0.00
C. row	9,644.11	4,669.87	11,431.17	9,295.15	13,018.25	0.00	0.00
3	R03	R04	R05	R06	R07	R08	R09
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	R10	R11	R12	R13	R14	R15	R16
	0.00	0.00	0.00	8,203.95	4,814.29	360.03	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	R17	R18	R19	R20	R21	R22	R23
	0.00	54.83	0.00	492.17	0.00	0.00	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	R24	R25	R26				
	0.00	0.00	0.00				
C. row	0.00	0.00	0.00				

* The values are expressed in soles.

A labor restriction was defined for each month, and the limitation of labor was given by the hours of labor time available on the family farm.

The result of this analysis is shown in Table 11. The final result gave the same combination of crops and the same area for each activity as was given in the second situation. This means that labor is not restrictive on this type of farm. The final value of the program was 46,620 soles. Deducting the cost of capital, the net income per family was 40,900.88 soles.

If we analyze the model and the solution carefully it is possible to observe that there are many hours of leisure per month. In order to increase the level of income in this situation part time jobs off the farm could be obtained, or the amount of land and water per farmer increased. It is apparent that under the conditions assumed the actual area of this farm was not in accord with the capacity of the family for work.

The fundamental problem in agriculture in the Chincha Valley is over supply of labor in relation to other resources. The large supply of farm laborers relative to the demand for them results, from the high farm birth rate and the current low labor mobility of these people, thus keeping the supply of farm labor excessive.

Technological advances, particularly those which encourage the substitution of capital in the form of machinery would have the immediate result of aggravating the labor surplus. However capital investment could be intensified in the form of fertilizer and better quality seeds. Such investments as these will help to increase output and consequently improve the level of income per family farm.

Table 11. Optimum farm plan and associated data for the Chincha Valley of Peru under restrictions of land, capital, water, labor, and maximum of one hectarea total area of yuca

Activity code	Activity description	Level of activity (hectareas)	Capital not used (soles)	Capital required (soles)	Cost of capital (soles)
P09	Lima beans	1.0148			
P11	Yuca	1.0000			
P06	Beans with corn	0.8334			
P07	Alfalfa	0.4074			
P04	Tomato	0.7407			
R01	Cap. Jan.		8,820.30	3,179.70	317.97
R02	Cap. Feb.		6,528.48	5,471.52	501.55
R03	Cap. March		4,760.85	7,239.15	603.26
R04	Cap. April		3,106.25	8,893.75	667.03
R05	Cap. May		1,099.40	10,900.60	726.70
R06	Cap. June		290.94	11,709.05	683.02
R07	Cap. July		6,069.56	5,930.44	296.52
R08	Cap. Aug.		4,786.12	7,213.88	300.57
R09	Cap. Sept.		3,818.16	8,181.84	272.72
R10	Cap. Oct.		5,785.42	6,214.58	155.36
R11	Cap. Nov.		2,086.10	9,913.90	165.23
R12	Cap. Dec.		8,440.87	3,559.13	29.65
Total		4.0000			4,719.58

Value of the program	45,620.46 soles
Cost of capital	4,719.58 soles
Net income of family farm	40,900.88 soles

Table 11. (Continued)

Activity code	Activity description	Water not used (irrigations)	Water required (irrigations)	Labor not * used (hours)	Labor * required (hours)
R15	Water, Jan.		7.000		
R16	Water, Feb.	3.963	4.037		
R17	Water, March	2.815	5.185		
R18	Water, April		10.000		
R19	Water, May	2.518	6.482		
R20	Water, June		10.000		
R21	Water, July	2.222	7.778		
R22	Water, Aug.	5.037	6.963		
R23	Water, Sept.	9.111	2.889		
R24	Water, Oct.	7.481	4.519		
R25	Water, Nov.	3.296	3.704		
R26	Water, Dec.	4.370	1.630		
R27	Labor, Jan.			450.48	29.52
R28	Labor, Feb.			331.92	148.08
R29	Labor, March			418.52	61.48
R30	Labor, April			313.17	166.83
R31	Labor, May			320.37	159.63
R32	Labor, June			92.77	387.23
R33	Labor, July			323.33	156.67
R34	Labor, Aug.			422.41	57.59
R35	Labor, Sept.			430.89	49.11
R36	Labor, Oct.			424.04	55.96
R37	Labor, Nov.			461.44	18.56
R38	Labor, Dec.			428.52	51.48

* The limitation for labor was assumed to be 480 hours per month.

The shadow prices for the Situation III displayed the same characteristics as those presented for Situation II.

D. Situation IV

Optimum farm plan assuming 8 hectareas of land;
12,000.00 soles monthly limitation of capital;
480 hours of labor per month; and monthly
limitation of water as indicated in Table 3

Situation IV differs from situation III in that the limit of the size of the farm has been increased to eight hectareas. The results are given in Table 12.

One should note an interesting result in the optimal solution for this situation. When the restriction on the land available was increased from 4 hectareas to 8 hectareas, the size of the farm increased but not by the full 4 hectareas allowable. Other restrictions were encountered which only allowed the size of the cultivated area to increase by 1.36 hectareas. These further restrictions were water and capital. The relative effects of these restrictions are illustrated by comparing the shadow prices of Situation III, Table 10, and Situation IV, Table 13. For instance, the shadow price of R15 (the January water restriction) was increased from 360 soles to 1,263 soles.

If we compare the result in Situation IV with the plan in Situation III, it is possible to observe that the value of the program has been increased from 45,620.46 soles to 54,541.12 soles. Deducting the cost of capital, the net income per family farm had been increased from 40,900.88 soles to 48,495.93 soles. This is a consequence of a larger area in the plan of 5.36 hectareas. Furthermore the number of activities has been

Table 12. Optimum farm plan and associated data for the Chincha Valley of Peru under restrictions of land, capital, water, labor and maximum of one hectarea total area in yuca -- the land limitation was increased to 8 hectareas

Activity code	Activity description	Level of activity (hectareas)	Capital not used (soles)	Capital used (soles)	Cost of capital (soles)
P01	Squash	1.114			
P09	Lima beans	0.781			
P05	Hybrid corn	0.340			
P11	Yuca	1.000			
P06	Beans with corn	0.634			
P02	Peas	0.782			
P04	Tomato	0.701			
R01	Cap. Jan.		5,621.92	6,378.08	637.80
R02	Cap. Feb.		3,198.17	8,801.83	806.83
R03	Cap. March		1,288.27	10,711.73	892.64
R04	Cap. April		0.00	12,000.00	900.00
R05	Cap. May		1,950.24	10,049.76	669.98
R06	Cap. June		1,076.06	10,923.94	637.22
R07	Cap. July		5,520.82	6,479.18	323.95
R08	Cap. Aug.		3,542.38	8,457.62	352.40
R09	Cap. Sept.		539.64	11,460.36	382.01
R10	Cap. Oct.		4,141.62	7,858.38	196.46
R11	Cap. Nov.		728.58	11,271.42	187.85
R12	Cap. Dec.		5,033.61	6,966.39	58.05
Total		5.360			6,045.19

Value of the program	54,541.12 soles
Cost of capital	6,045.19 soles
Net income per family farm	48,495.93 soles

Table 12. (Continued)

Activity code	Activity description	Water not used (irrigations)	Water required (irrigations)	Labor not * used (hours)	Labor * required (hours)
R15	Water, Jan.		7.0000		
R16	Water, Feb.	1.5796	6.4204		
R17	Water, March	0.8783	7.1217		
R18	Water, April		10.0000		
R19	Water, May		9.0000		
R20	Water, June	0.3810	9.6190		
R21	Water, July		10.0000		
R22	Water, Aug.	1.5586	10.4414		
R23	Water, Sept.		12.0000		
R24	Water, Oct.	6.4649	5.5351		
R25	Water, Nov.	0.6004	6.3996		
R26	Water, Dec.	1.5488	4.4512		
R27	Labor, Jan.			426.92	53.08
R28	Labor, Feb.			300.80	179.20
R29	Labor, March			392.92	87.08
R30	Labor, April			350.56	129.44
R31	Labor, May			343.54	136.46
R32	Labor, June			83.16	396.84
R33	Labor, July			293.40	186.60
R34	Labor, Aug.			380.58	99.42
R35	Labor, Sept.			426.68	53.32
R36	Labor, Oct.			387.36	92.64
R37	Labor, Nov.			438.56	41.44
R38	Labor, Dec.			320.11	159.89
R13	Land not used	2.6496 hectareas			

* The limitation for labor was assumed to be 480 hours per month.

Table 13. Shadow prices and cost row of real and disposal activities*

1	B	P01	P02	P03	P04	P05	P06
	54,541.11	0.00	0.00	857.79	0.00	0.00	0.00
C. row	0.00	9,023.00	7,617.13	6,927.99	11,535.51	6,030.39	10,182.54
2	P07	P08	P09	P10	P11	R01	R02
	1,035.82	7,554.30	0.00	1,474.43	0.00	0.00	0.00
C. row	9,644.11	4,669.87	11,431.17	9,295.15	13,018.25	0.00	0.00
3	R03	R04	R05	R06	R07	R08	R09
	0.00	0.71	0.00	0.00	0.00	0.00	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	R10	R11	R12	R13	R14	R15	R16
	0.00	0.00	0.00	0.00	11,919.51	1,263.00	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	R17	R18	R19	R20	R21	R22	R23
	0.00	891.83	466,47	0.00	755.38	0.00	375.57
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	R24	R25	R26	R27	R28	R29	R30
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	R31	R32	R33	R34	R35	R36	R37
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	R38						
	0.00						
C. row	0.00						

* The values are expressed in soles.

increased to seven.

Another interesting observation in the new plan is that the area of tomatoes, beans intercropped with corn and yuca remained almost at the same level. Also, the alfalfa activity was eliminated in this plan and replaced by other activities; squash 1.114 hectareas, hybrid corn 0.340 hectareas and peas 0.782 hectareas. These changes resulted from the need for a more efficient use of available water. The program therefore selected activities with lower needs for water in the critical months of January, April, and July. In these months the impact of increasing the supply of water was greater as indicated by the shadow prices in Table 13. Furthermore alfalfa requires more capital than the combination of hybrid corn and peas for the month of April.

Shadow prices: (see Table 13). If we replace one hectarea of a real activity now in the optimal solution, holding the area of the farm at 5.36 hectareas, the value of the program would be reduced in each case by the following amounts:

Activity increased by one hectarea		Reduction in the value of the program, soles
P03	Sweet potato	857.79
P07	Alfalfa	1,035.82
P08	Cotton	7,554.30
P10	Corn	1,474.43

This last unit of each of the resources which were restrictive to this program, contribute the following amount to the value of the program.

Contribution of last unit of resource to the value of the program:

R04	Capital, April, one sol	0.71 soles
R15	One irrigation, January	1,263.00 soles
R18	One irrigation, April	891.83 soles
R19	One irrigation, May	466.68 soles
R21	One irrigation, July	755.38 soles
R23	One irrigation, September	375.58 soles

This means that if we increase by one-hundred soles the level of capital in April the value of the program would be increased by about 71 soles. If we increase by one hectareas the area of yuca, the value of the program would be increased by 11,919.12 soles. If we increase the water supply by one irrigation (3,456 m^3) in January the value of the program would be increased by 1,263.00 soles. If we increase the water supply by one irrigation in April, the value of the plan would be increased by 891.83 soles. We would be able to increase the value of the program by increasing the supply of water by one irrigation in May, July, and September by 466, 755, and 375 soles respectively.

Therefore in order to increase the income of the family farm there must be an increase in capital in April, and the supply of water per farmer in January, May, July, and September.

E. Situation V

Optimum farm plan assuming 8 hectareas of land;
16,000.00 soles monthly limitation of capital;
480 hours of labor per month; and monthly
restriction of water as indicated in Table 3

In the short run it is easier to increase the supply of capital than the supply of water. Situation V investigates the effect of increasing the availability of capital from 12,000.00 soles to 16,000.00 soles per month.

The results of this computation are shown in Table 14.

If we compare the result of this plan with that of Situation IV, it is possible to observe that the value of the program has been increased from 54,541.12 soles to 55,303.52 soles. This is a consequence of a larger amount of capital used in April and November, 13,406.53 and 12,912.85 soles respectively. Deducting the cost of capital the net income per family farm had been increased from 48,495.93 soles in Situation IV to 48,730.07 soles in Situation V.

The number of activities has been increased from seven to nine. The cultivated area considered in Situation IV has changed very little for Situation V. Instead two new activities were selected: alfalfa, 0.1438 hectareas; and sweet potato, 0.09 hectareas. This change is a consequence of the availability of capital being increased in April and November.

Shadow prices: (see Table 15). If we replace one hectarea of real activity now in the optimal solution by each of the following real activities which were not in the optimal solution, the value of the program would be reduced in each case by the following amount:

Activity increased by one hectarea	Reduction in the value of the program, soles
P08	2,050.63
P10	887.39

As in Situation IV labor is not a limitation in this type of farm. With the exception of June, there is a high redundancy of labor in every month.

Since the limitation of capital was changed from 12,000.00 soles to

Table 14. Optimum farm plan and associated data for the Chincha Valley of Peru under the following restrictions: land, 8 hectareas; capital per month, 16,000.00 soles; labor per month, 480 hours; and monthly limitation of water

Activity code	Activity description	Level of activity (hectareas)	Capital not used (soles)	Capital required (soles)	Cost of capital (soles)
P01	Squash	1.3562			
P11	Yuca	1.0000			
P07	Alfalfa	0.1438			
P03	Sweet potato	0.0949			
P06	Beans with corn	0.2635			
P09	Lima beans	0.9717			
P05	Hybrid corn	0.1646			
P02	Peas	0.7708			
P04	Tomato	0.6371			
R01	Cap. Jan.		8,628.13	7,371.87	737.18
R02	Cap. Feb.		5,971.55	10,028.45	919.27
R03	Cap. March		4,082.74	11,917.26	993.10
R04	Cap. April		2,593.47	13,406.53	1,005.48
R05	Cap. May		5,406.98	10,593.02	706.20
R06	Cap. June		4,846.87	11,153.13	650.59
R07	Cap. July		9,059.18	6,940.82	347.04
R08	Cap. Aug.		7,672.36	8,372.64	346.98
R09	Cap. Sept.		4,885.37	11,114.63	370.48
R10	Cap. Oct.		7,228.95	8,771.05	219.27
R11	Cap. Nov.		3,087.15	12,912.85	215.21
R12	Cap. Dec.		8,481.56	7,518.44	62.65
Total		5.4026			6,573.45

Value of the program	55,303.52 soles
Cost of capital	6,573.45 soles
Net income for family farm	48,730.07 soles

Table 14. (Continued)

Activity code	Activity description	Water not used (irrigation)	Water required (irrigation)	Labor not used (hours) *	Labor required (hours) *
R15	Water, Jan.		7.0000		
R16	Water, Feb.	0.8360	7.1640		
R17	Water, March	0.0550	7.9450		
R18	Water, April		10.0000		
R19	Water, May		9.0000		
R20	Water, June		10.0000		
R21	Water, July		10.0000		
R22	Water, Aug.	1.6814	10.3186		
R23	Water, Sept.		12.0000		
R24	Water, Oct.	6.7663	5.2337		
R25	Water, Nov.		7.0000		
R26	Water, Dec.		6.0000		
R27	Labor, Jan.			412.93	67.07
R28	Labor, Feb.			311.48	168.52
R29	Labor, March			387.99	92.01
R30	Labor, April			318.55	161.45
R31	Labor, May			328.18	151.82
R32	Labor, June			109.66	270.34
R33	Labor, July			271.22	208.78
R34	Labor, Aug.			414.00	66.00
R35	Labor, Sept.			403.25	76.75
R36	Labor, Oct.			398.63	81.37
R37	Labor, Nov.			441.09	38.91
R38	Labor, Dec.			339.94	140.06
R13	Land not used	2.5974 hectareas			

* The limitation for labor was assumed to be 480 hours per month.

Table 15. Shadow prices and cost row of real and disposal activities*

1	B	P01	P02	P03	P04	P05	P06
	55,303.51	0.00	0.00	0.00	0.00	0.00	0.00
C. row	0.00	9,023.00	7,617.13	6,927.99	11,535.51	6,030.39	10,182.54
2	P07	P08	P09	P10	P11	R01	R02
	0.00	2,050.65	0.00	887.39	0.00	0.00	0.00
C. row	9,644.11	4,669.87	11,431.17	9,295.15	13,018.25	0.00	0.00
3	R03	R04	R05	R06	R07	R08	R09
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	R10	R11	R12	R13	R14	R15	R16
	0.00	0.00	0.00	0.00	13,018.24	1,350.17	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	R17	R18	R19	R20	R21	R22	R23
	0.00	407.47	187.62	1,396.50	66.05	0.00	888.92
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	R24	R25	R26	R27	R28	R29	R30
	0.00	183.28	82.48	0.00	0.00	0.00	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	R31	R32	R33	R34	R35	R36	R37
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. row	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	R38						
	0.00						
C. row	0.00						

* The values are expressed in soles.

to 16,000.00 soles, there was no critical month with respect to capital for this type of farm. Therefore, the shadow price shows that the monthly marginal productivity of capital is zero.

If we analyze the shadow prices it is possible to observe possible opportunities for increasing the level of income by increasing the water supply per farmer in January, April, May, June, July, September, November and December.

The contribution to income in soles of using one more irrigation during the restrictive months is the following:

R15	January	1,350.18
R18	April	407.48
R19	May	187.63
R20	June	1,396.51
R21	July	66.05
R23	September	888.92
R25	November	183.28
R26	December	82.48

The above results indicate that increasing the water supply in January, June, and September would have a significant impact on the improvement of the level of income.

The results shown for Situation V indicate that satisfying the objective of raising the level of income of the farm family depends primarily upon increasing the supply of available water per farm.

VI. CONCLUSIONS AND RECOMMENDATIONS

The conclusions of this study are: (1) that the small farms of the Chincha Valley have an excess of family labor and (2) the main resource restrictions are water and capital.

In order to have a more realistic basis for planning, the government of Peru should make studies of determination of elasticities of demand and supply of all the agricultural products.

In situation I the months of maximum capital requirements were June and November. The investment of capital in each of these months would give a return of sixteen percent and ten percent per annum respectively.

In situations II and III the shadow prices show that additional investment would not effect the level of income favorably.

In situation IV when the land available per farm was increased from 4 hectareas to 8 hectareas, the shadow prices show that one unit of capital invested in April would give a return of seventy-one percent per annum.

In all the situations where the water restrictions were included, a high marginal product for the water restriction was shown. For instance, in situation II and III an increase of one irrigation in January would increase the level of income by 360.04 soles.

In situation IV an increase in one irrigation in January would increase the level of income by 1,263.51 soles. Furthermore, it would be possible to increase the level of income if we increase the number of irrigations by one in April, May, July, or September.

In situation V where the restrictions on capital and land were

relaxed, the water restriction became critical in more months, and defined a new crop plan for the farm. The increase of water by one irrigation would increase the level of income in January, June, and September by 1,350.18, 1,396.51 and 888.92 soles respectively.

These results enable us to conclude that in order to increase the level of income, it is necessary to increase the water supply per farmer. Perhaps it is necessary to increase the number of wells. To make this decision a detailed study of water resources in the Chincha Valley is needed. If a sufficient water supply per farmer were assured, it would be possible to study the necessary increment of land and capital that would make full use of the work capacity of the family farm.

Where labor was included as a restriction in the situations studied, the results indicate a surplus of farm labor. This surplus could be reduced by the use of the following type of policies: (1) by offering the same opportunity of education in this rural area as in the cities; (2) by increasing vocational education and providing industrial opportunities to attract the young people out of agriculture.

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